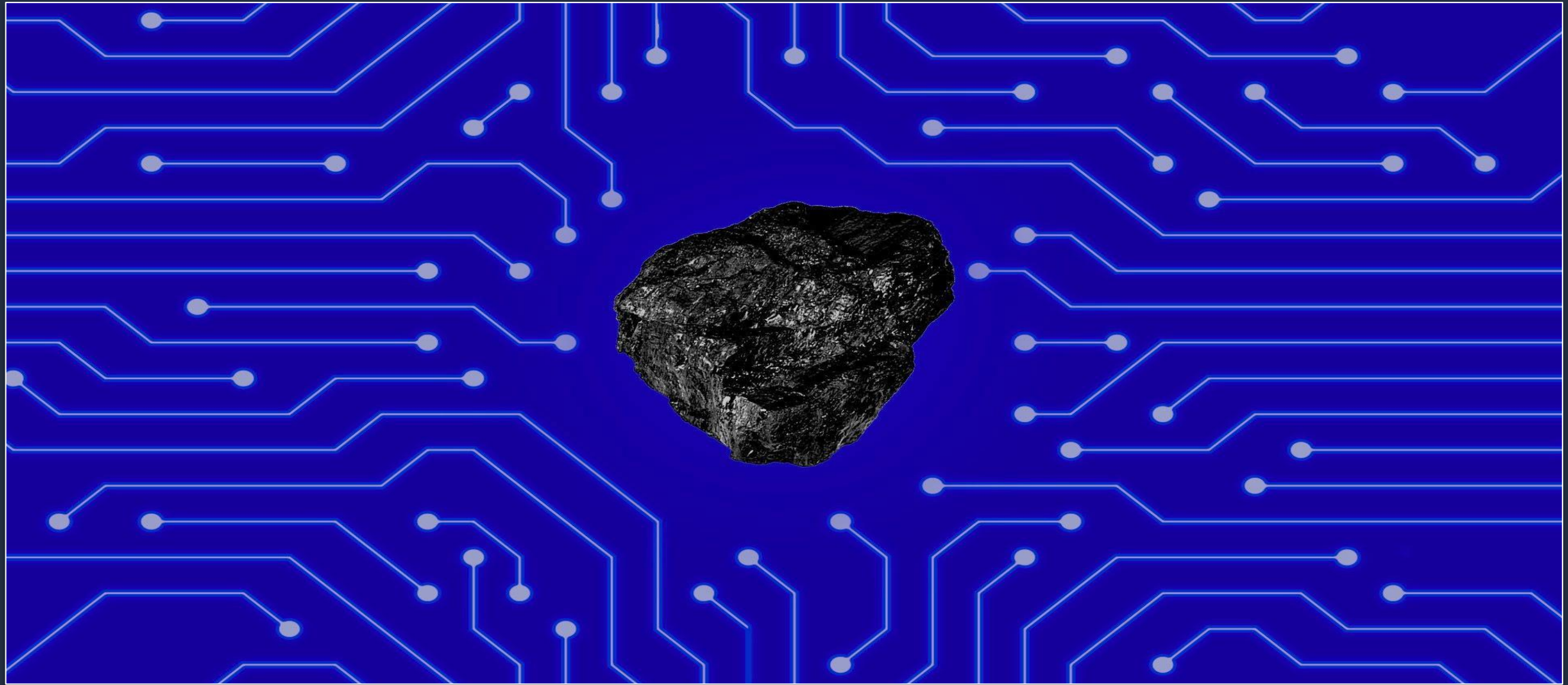


The New Carbon Age

Advanced Carbon Products and Materials from Coal



U.S. Dept. of Energy-
National Energy Technology Laboratory
2020 Carbon X Summit

Randall W. Atkins—Chairman & CEO, Ramaco Carbon

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Does Coal Have a Future?

- Since 2017, our industry has seen twelve major bankruptcies or restructurings announced by both thermal and met coal producers in CAPP, ILB and PRB.
- Both political parties are looking for long-term solutions to this industrial, strategic and socio-economic crisis.
- Since 2013, **Ramaco Carbon** has embarked on an unconventional, technology-focused approach to fundamentally change how we perceive and use coal.
- We started from the concept of mimicking the chemical focus of metallurgical coal.
- **Our Mantra:** “Coal is too valuable to burn”...
- **Our Focus:** Create a vertically integrated Coal Tech platform which uses thermal coal as a carbon precursor to make lower cost, higher value advanced products and materials.
- The National Coal Council’s May 2019 report to then Sec. of Energy Rick Perry entitled “**Coal in a New Carbon Age**” provides a blueprint.



Our Goals

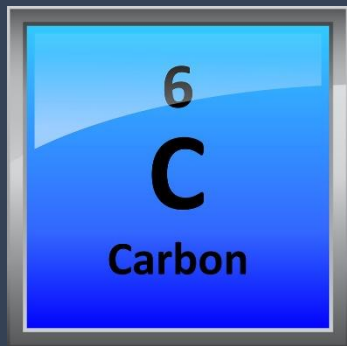
- To transform the coal industry. Make it into a provider of higher tech non-combustion feedstock for advanced carbon products and materials which are more environmentally friendly.
- Think of calling it “Carbon Ore” ...
- We start by borrowing existing CTL conversion technologies and combine them with new advancements in carbon and material research, as well as new forms of manufacturing.
- Thermal coal is then for a more valuable end use than power.
- The price paid for thermal coal could then increase. This could then make stranded, higher-cost thermal coal reserves economic to mine.
- The amount of coal required for these potential non-combustion uses can be enormous. China currently uses 300+ million tons annually in this manner. *There are almost 150 CTL/C new plants under construction in China and approx. 370 more in the pipeline.*
- Within five years that figure in China is~ 500 million tons per year used for coal to products. That is roughly the entire amount (~530 million tons) of coal estimated to be produced in the US in 2020.



The Irony is...

Perhaps coal is the future...





Carbon (from Coal)...

An Agent of *Mass Disruption*

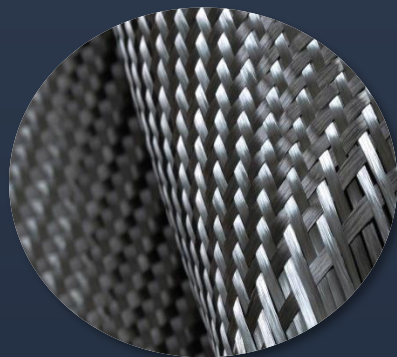
- **Carbon** is becoming the dominant “*advanced material*” of the 21st Century — think carbon fiber, graphene, graphite and carbon resins. We’re perhaps entering the **Carbon Age**.
- The United States could lead this wave of innovation. It has both the technology and the coal reserves.
- The simple solution...we make less expensive carbon products and materials from coal... instead of petroleum.
- Cheaper advanced materials made from coal could enhance or even replace both key metals (i.e. steel, aluminum), as well as basic building products (i.e. cement, asphalt, rebar, roof shingles). Carbon also has applications in chemicals, resins, and even life sciences.
- Like the internet, the use of coal as a low cost precursor for basic materials could lower manufacturing costs on a massive scale and require tremendous volumes of coal - a positive mass disruption.
- And...just a few new large scale alternative uses for coal could create a new demand inflection point for the entire US coal industry..

The Dramatic Cost Advantage of Using Carbon from Coal

Coal's potential is to make advanced carbon materials that are stronger, lighter, and cheaper.

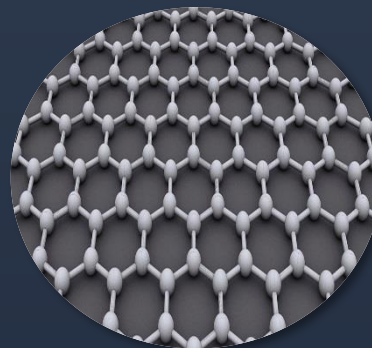
The key to coal's advantage ...is *cost*. There is the same amount of carbon in a ton of coal and a ton of petroleum, but coal currently has over a 20 X cost advantage.

Basic materials made from coal can be made cheaper than from using petroleum:



Carbon Fiber

Carbon fiber is 50% the weight of aluminum but 4X as strong. It is 25% the weight of steel but 2X as strong.



Graphene

Used to conduct heat and electricity, this material is thinner than paper and can be harder than a diamond.



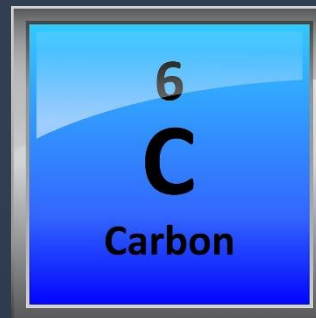
Graphite

Used to make brake linings, lubricants, and molds in foundries, and in the production of steel.

Cost Equivalence of Carbon from Coal vs. Petroleum (~20 X Cheaper...even Today)



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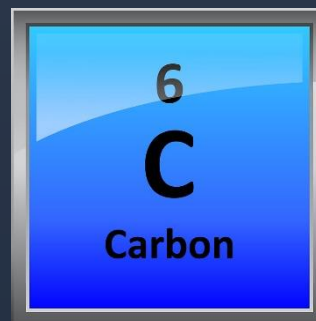
= \$12 per ton

1 Ton of PRB Coal

1400 lbs. of Carbon



=



= \$280 per ton
@ \$40 per barrel
(lowest crude price in ~70
years)

1 Ton of Petroleum =
7 Barrels of Crude Oil

1400 lbs. of Carbon

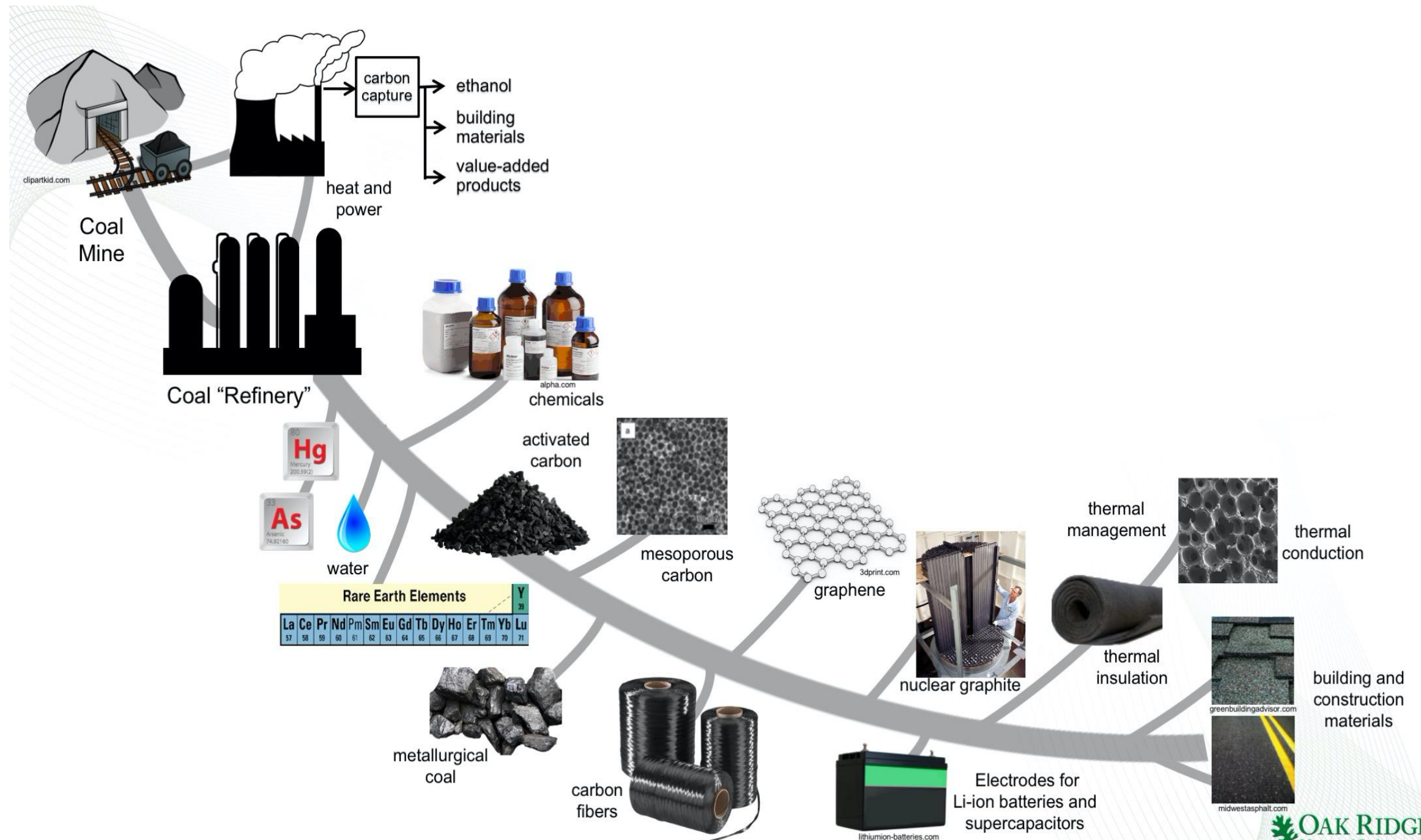
Where Are We Headed?



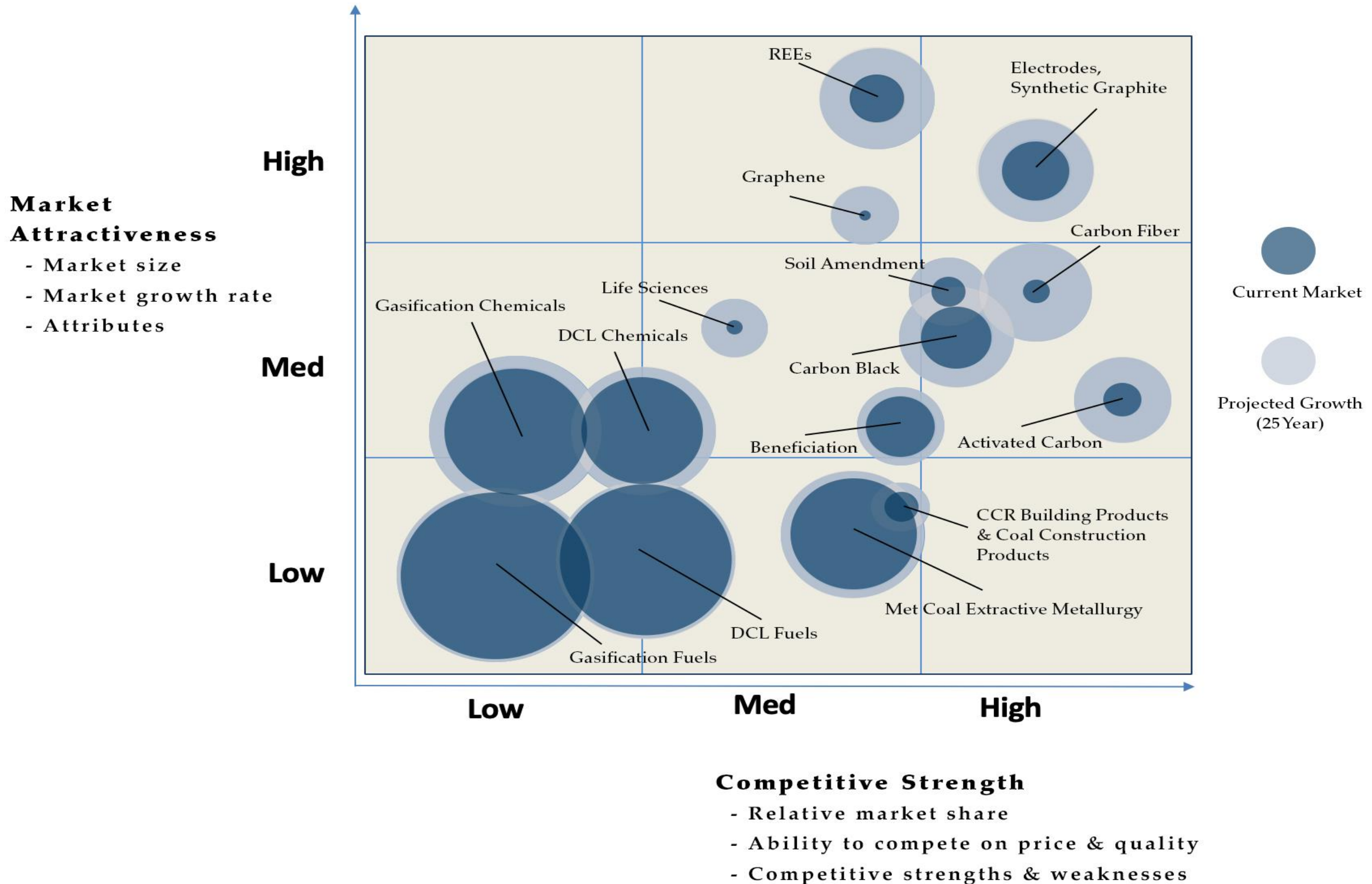
The New Coal to Advanced Carbon Products Tree

7

The New Coal Tree



What Are the New Product Markets



The Coal to Product Value Proposition

**COAL
FEEDSTOCKS**
\$30-60/ton (2017 spot price)

MATERIALS MANUFACTURING

CARBON PRODUCTS

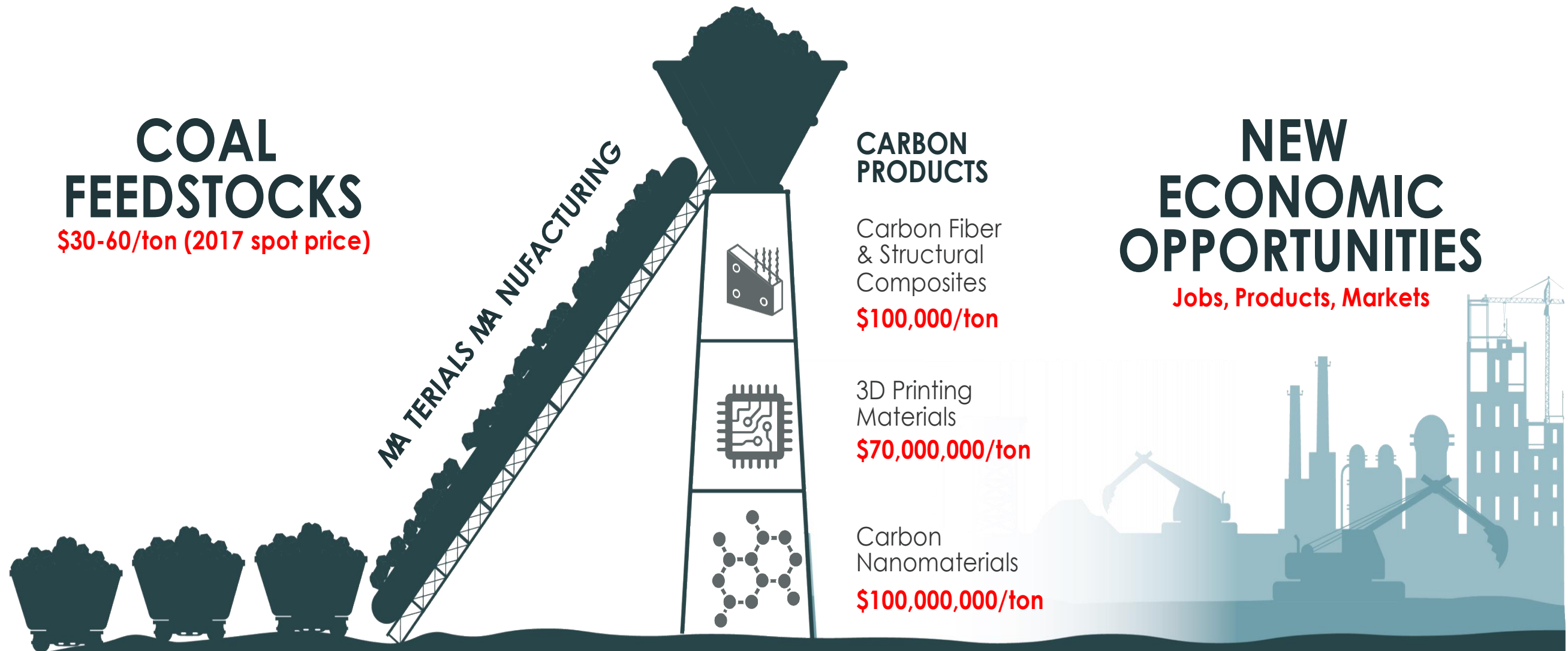
Carbon Fiber
& Structural
Composites
\$100,000/ton

3D Printing
Materials
\$70,000,000/ton

Carbon
Nanomaterials
\$100,000,000/ton

**NEW
ECONOMIC
OPPORTUNITIES**

Jobs, Products, Markets



Ramaco Carbon: A Vertically Integrated Coal Tech company



COAL RESERVES

Ramaco Carbon owns the Brook Mine in Wyoming, a 1.1 billion ton privately owned coal resource.

Ramaco Coal also owns 250+ million tons of metallurgical coal reserves mostly in West Virginia.



RESEARCH PARK

The iCAM in Wyoming will be completed this Summer. An additional lab has now opened in West Virginia.

These labs will coordinate research to incubate and commercialize coal-based carbon products, from bench thru pilot stage.



INDUSTRIAL PARK

The iPark is a 100+ acre “coal to products” mine-mouth industrial park in Wyoming.

Mine-mouth manufacturing operations will use coal from the Brook Mine to make advanced carbon products and materials.



Unique Partners

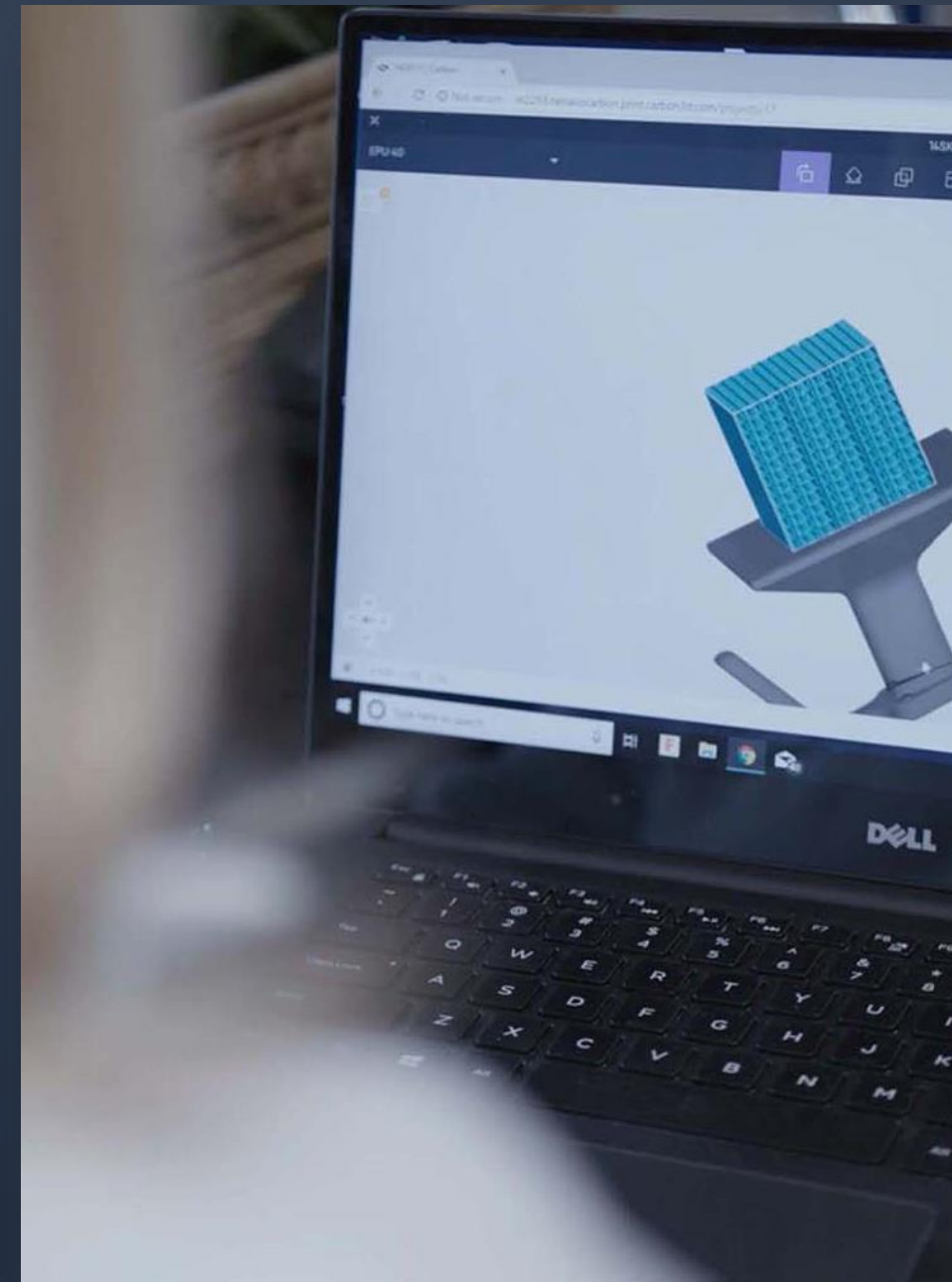
- **Ramaco Carbon** is privileged to be working with some of the top research institutes, universities, and strategic groups, who form our core research and development network.
- We are also partnered with both NETL and Oak Ridge National Laboratory under CRADAs focused on developing a variety of coal process and carbon product technologies.
- Ramaco Carbon is now involved in **five grants from the Department of Energy** to explore novel uses of coal to make carbon products.
- For the past two summers over 50 scientists have come together for the **Ramaco Research Rodeo (the “R3”)**, a private “coal-to-products” research conference in Sheridan, Wyoming.

Partners include:

- National Energy Technology Laboratory
- Oak Ridge National Laboratory
- MIT- The Grossman Materials Group
- Fluor Corporation
- TerraPower, LLC
- Axens
- West Virginia Univ.
- Univ. of Illinois-Chicago
- Rice University
- Western Research Institute
- Southern Research Institute

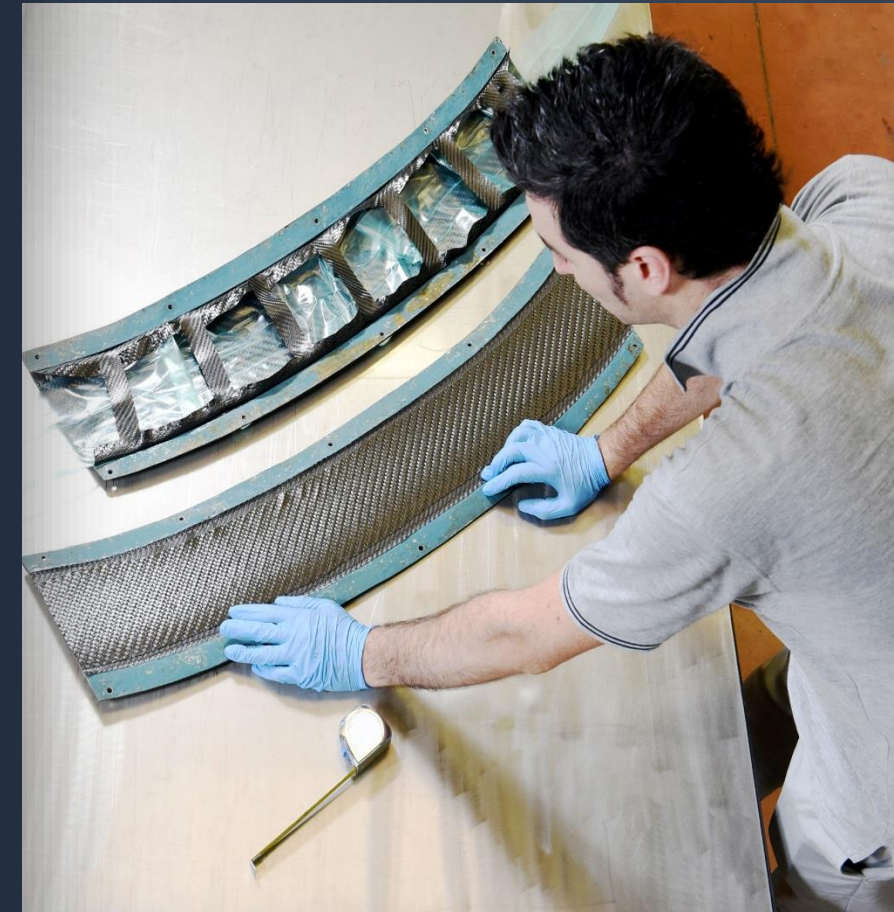
Our Product Focus

- **Ramaco** is focusing on four broad carbon based uses :
 - 1) Coal to Pitches and Carbon Fibers
 - 2) Coal to Building Products
 - 3) Coal to Advanced Materials- REEs/Resins
 - 4) Coal to Life Science Products
- These uses have both a high margin value proposition and in many cases also require large coal volumes.




Carbon Fiber-Coal to Cars

- Of roughly 100 million vehicles made each year, carbon fiber is used in less than 100,000 — despite benefits in gas mileage, strength, and more.
- Carbon fiber is 4x lighter than steel and 2x as strong. It is 2x lighter than aluminum and 4x as strong.
- The barrier is its high cost. Carbon fiber now made from petroleum precursor is 8x more expensive than steel.
- We need to drive the price of the coal-based precursor beneath the “tipping point.”
- Carbon fiber then becomes an affordable alternative to steel.
- Carbon fiber cars then move from niche markets — such as F1 racing — to mass markets.
- Big Environmental Advantage - Lighter vehicles equal less gas consumption.
- We are in our 3rd year of a DOE grant with several national partners nicknamed “Coal to Cars.” The Goal- use coal to make low cost carbon fiber for vehicles.




And perhaps not just Cars

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Coal Seeks New Life as Carbon Fiber for Submarines

By **Tim Loh** and **Patrick Martin**
September 13, 2017, 7:00 PM EDT *Updated on* September 14, 2017, 9:53 AM EDT
From **Climate Changed**

- One of many uses scientists study as U.S. utilities burn less
- New markets won't restore lost mine jobs, but may halt slide

The 30-foot hull of an experimental mini-sub is helping to show how the U.S. may be able to redeploy the mountain of coal that power plants are no longer burning.

Researchers at the Oak Ridge National Laboratory in Tennessee used carbon fibers to build the submersible for the U.S. Navy with a [3-D printer](#), demonstrating the promise of new manufacturing techniques that are faster, cheaper and more flexible. But it also offers inspiration to scientists looking to turn America's vast reserves of coal into advanced materials, including carbon fibers now made using petroleum-based polymers.

Most Read

- 1 A \$150 Billion Misfire: How Disaster Models Got Irma Wrong
- 2 NFL TV Ratings Slump Again
- 3 Jamie Dimon Slams Bitcoin as a 'Fraud'
- 4 Pandit Says 30% of Bank Jobs May Disappear in Next Five Years
- 5 Apple Unveils iPhone X With New Display as Rivals Grow

Coal to Building Products

Another disruptive large-scale use for coal is building products, which has the potential to require greater coal volumes than even carbon fiber.

- **Rebar** — Carbon fiber rebar can provide flexibility to concrete structures, is lighter than current rebar, and does not rust.
- **Roofing** — Coal-based asphalt roof shingles could become a regular feature of buildings.
- **Repair Aging Infrastructure** (think bridge renovations): Can be molded around existing older infrastructure to provide structural strength, increasing lifespan by 2-3x.
- Perhaps coal can be used to create a new form of **Basic Carbon Building Material**... *before* we run out of steel, wood and concrete.



Coal to 3D Resins for Tomorrow's new form of Manufacturing



Wyoming iPark
SpeedCell Printers



Coal to Rare Earth Minerals

4

Coal is a complex compound that contains many valuable elements of the periodic table including critical minerals and rare-earth elements.



| | | | | | | | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| La | Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu | Y |
| 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 39 |

SPEAKERS

Praseodymium
Neodymium
Dysprosium
Gadolinium

COLOR SCREEN

Yttrium
Europium
Gadolinium
Terbium

CAMERA

Lanthanum
Yttrium

CIRCUITRY

Neodymium
Dysprosium
(Tantalum)

BATTERY

Lanthanum
Praseodymium
(Lithium)

VIBRATION

Neodymium
(Tungsten)

Rare-Earth elements enable many technologies that are essential for the energy sector, consumer electronics and national security



Beyond Products-Another Objective ? *People and Coal "CAMPs"*

- **Create an Ecosystem of advanced manufacturing hubs** around the country, producing carbon products from coal.
 - We call them Coal "CAMP"s (Carbon Advanced Manufacturing and Production centers).
- **Locate new CAMPs, in coal-producing areas.** Mine-mouth manufacturing logistical advantages and access to skilled coal mining talent.
 - "Repurpose" older coal communities into advanced high tech manufacturing hubs.
- **Build an innovative, higher tech future for the coal industry and its workers** that is independent of power trends and environmental concerns.

The Path Forward: Key Points

#1

The past few years have been very difficult for the coal industry. It is getting worse.

To survive... Let's think outside the box.

#2

The U.S. has the coal resource base and the technological prowess to both lead...

And fundamentally reinvent the coal industry.

#3

Innovation and research is the first step.

But that R&D must be leveraged, supported and nurtured..

#4

Federal and State government support is critical to realizing the scale of the opportunity.

#5

Coal could have a much brighter future in a high tech world than we can imagine.

#6

We just need to unlock the **Magic of Carbon** contained in every **Lump of Coal!**



www.ramacocarbon.com

